CHAPTER 4
Monitoring and Evaluating Success

TERMINOLOGY

In order to promote effective restoration and mitigation, one must have an unambiguous definition of success. As seen in the comparative analysis (above), there are many criteria that have been used for evaluating planting success (Table 1.9). It is our opinion that simple measures of seagrass coverage and persistence are at this time: (1) the most parsimonious indicators of many other seagrass bed functional attributes, and (2) constitute the most pragmatic choices of monitoring parameters under the present system of resource management.

Through seagrass planting, one is attempting to establish a viable plant community that performs habitat functions equivalent to ones that were lost. The evaluation of all seagrass ecosystem functions (e.g., sediment stabilization, biomass production, nutrient cycling, secondary production) is almost always beyond the resources of any project. However, we have been conducting research with the goal of identifying diagnostic parameters which can be inexpensively monitored so as to infer with reasonable certainty that specific functional attributes have been restored. Many habitat functions (e.g., animal abundance, taxonomic composition, complexity of the seagrass canopy, macroalgal abundance) appear to relate simply to coverage and persistence of that coverage; parameters that are inexpensively monitored (Fonseca et al. 1990, Meyer et al. 1990, Fonseca et al. 1996a,b). Although these findings are limited to studies in Tampa Bay, FL, and southern Core Sound, NC, we feel that they provide sufficient basis to guide resource managers in some decisions regarding planting success. However, we stress that validation of the following generalizations should

be an ongoing process with an emphasis on extending geographic replication. Therefore, we define seagrass planting success as:

> **the unassisted persistence of the required acreage of seagrass coverage for a prescribed period of time (suggested minimum of five years).**

The required acreage is a result of the replanting ratio (habitat acreage restored / habitat acreage lost) which is in turn a function of agency policy and the nature of the planting site. Fonseca (1989a, 1992, 1994) described what to monitor, how to perform the monitoring, and how to interpret the results. The following are modified excerpts from those publications.

Monitoring Specifications

No one data type can stand alone in a monitoring program (Fonseca et al. 1987c, Fonseca 1989a). Several factors must be considered and these lead to an ecologically valid characterization of seagrass planting success. Sufficient monitoring should be conducted to ensure that any contracted work was performed to specifications. However, in any situation, monitoring of planting performance using standard methods provides the basis for mid-course corrections (Fonseca 1989a) and improved planning of subsequent projects.

Survival

The number of PUs that survive should be recorded. This may be expressed as a percentage of the original number, but the actual whole number is critical as well. If a planting site is sufficiently small (~500-1000 PU), all PUs should be surveyed for presence or absence (survival survey). The existence of a single short shoot on a PU indicates its survival (hopefully that shoot is associated with a rhizome meristem, otherwise subsequent vegetative growth will not occur). If a site is large, then randomly (not arbitrarily) selected rows or subsections (area in m²) should be sampled. Since each row or subsection is actually the level of replication, at least 10 replicate rows or subsections should be performed at the level which one wishes to generalize their findings (e.g., over the whole planting site). At the very least, stabilization of the running mean of survival should be obtained as a measure of statistical adequacy.

Areal Coverage

A **random** (as opposed to arbitrary) sample of area covered (m²) per planting unit should be recorded until coalescence (the point where individual PUs grow

together and the PU origin of individual shoots cannot be readily observed). The area covered by a PU may be measured by recording the average of two perpendicular width measurements (in meters) of the PU over the bottom. These numbers are averaged, divided by 2, squared, and multiplied by π (i.e., $\pi*r^2$) to compute the area of a circle, and in this case, the PU. This procedure tends to give a higher value than use of a quadrat with 25 cm^2 resolution, particularly when PU expansion is not uniformly circular. With a quadrat survey, a 50 x 50 cm quadrat, divided into 5 x 5 cm grids (string on 5 cm centers across the quadrat frame) is laid over the PU and filled grids counted. In this case, the number of 5 x 5 cm grids (or half grids if there are only 1 or 2 shoots in the 5 x 5 cm grid) that have seagrass shoots are totaled and converted to meters square of cover for the PU. The quadrat method is more appropriate for seagrasses that propagate by long runners (e.g. shoalgrass), and do not form a clearly radial growth pattern (e.g. eelgrass). The number of surviving PUs may then be multiplied by the average area per PU to determine the area covered on the planting site. After coalescence, the area of bottom covered should be surveyed using randomized grid samples at the 1 m^2 scale width (Fonseca et al. 1985). These data may be used to assess persistence of the planting as well as total seagrass coverage.

For very large seagrass plants whose rhizome mats do not significantly interdigitate (e.g., *Zostera marina* on the West Coast of the U.S., R. Thom, Battelle Pacific Northwest Lab., Sequim, WA, pers. com.; pers. obs.), post-coalescence techniques may actually be more appropriate with the 0.0625 m^2 resolution being perhaps better scaled to this plant size and spacing.

Number of Shoots

Random samples should be collected to measure the number of shoots per PU. The data from pre-coalescence surveys may be used to compare performance relative to other, local plantings by plotting the average number of shoots per PU as well as shoot density (number of shoots PU^{-1}/area PU^{-1}) over time. The comparison may be statistical or visual on a graph (which often suffices to detect grossly different population growth rates). Early stage PUs that are still associated with the anchor are artificially clustered by the nature of the PU show an artificially high m^{-2} shoot density, sometimes ten times higher than a reference site. When shoot density of a PU is essentially equal to that of reference sites, this indicates that the plants have spread to a point where they are occupying area in a way consistent with long-term establishment and that successful colonization has occurred. This is an important indicator of planting performance and environmental suitability of a site. Shoot number is recommended in addition to areal coverage because shoot addition is a more accurate means of assessing the asexual reproductive vigor of the plantings. Also, areal coverage varies with the environmental setting of the planting. For example, in areas of

high current shoots grow more densely. Without shoot number data, the patchy pattern and low areal coverage in high current environments could be erroneously ascribed to poor planting performance instead of a natural pattern of growth. Moreover, the size of the naturally-occurring patches gives an idea of the expected form of planted patches (see section on "Spacing of Planting Units," above).

MONITORING FREQUENCY

Survival, areal coverage, and number of short shoots per PU are straightforward measures, although they usually require snorkeling or SCUBA diving (a factor that is surprisingly not considered, or equipped for, by many attempting these data collections). An individual can be trained to count in a few hours, and can count individual PUs in 5-10 minutes or less at early stages of post-planting growth.

Monitoring of shoot numbers, area covered per PU, and shoot density should, at a minimum, be done quarterly for the first year after planting and biannually thereafter for a minimum of four more years (a minimum total of five years). After PUs begin to coalesce and the PU from which shoots originated can no longer be discerned, areal coverage and shoot density data should be recorded and counts on a PU basis suspended. However, any replanting after the initial planting resets the monitoring clock and monitoring frequency to time zero.

However, as suggested by Fonseca (1989a), mistakes may be made in selecting a site. Repeated plantings may fail. There needs to be some decision sequence to break the cycle of replanting in perpetuity before managers lose control of the process. We propose the following sequence. For *Zostera* spp, *Halodule*, *Syringodium*, *Ruppia*, and *Halophila* spp., monitoring should continue for a minimum of three years (Figure 4.1). For *Thalassia* and *Phyllospadix*, longer periods of time may be required. While the time course for monitoring *Phyllospadix* spp. has not been determined, its slow vegetative growth suggests that 5-10 years may be an appropriate length to begin with, with comparatively quiescent areas monitored for 5 years while more wave-exposed sites monitored for 10 years. For *Thalassia*, restoration of the rhizome mat could conceivably take a century. Because most permits cannot be followed for anywhere close to that time, we suggest that 5-10 years may also be appropriate. Duration of monitoring may also have to be extended and/or intensified for sites susceptible to subsequent human impacts such as propeller scarring.

If at any time a loss of PUs occurs, then replanting (remedial planting) should be done. Because this tends to happen with greater frequency soon after planting, heavy arrows are used (Figure 4.1) to indicate conveyance to Replanting #1; less

SEQUENCING OF THE SUCCESS CRITERIA

Year 1   Year 2   Year 3

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monitoring steps

Time 0

portions lost or not on
predicted recovery curve

Replant # 1

monitoring steps

New
Time 0

Replant # 2

monitoring steps
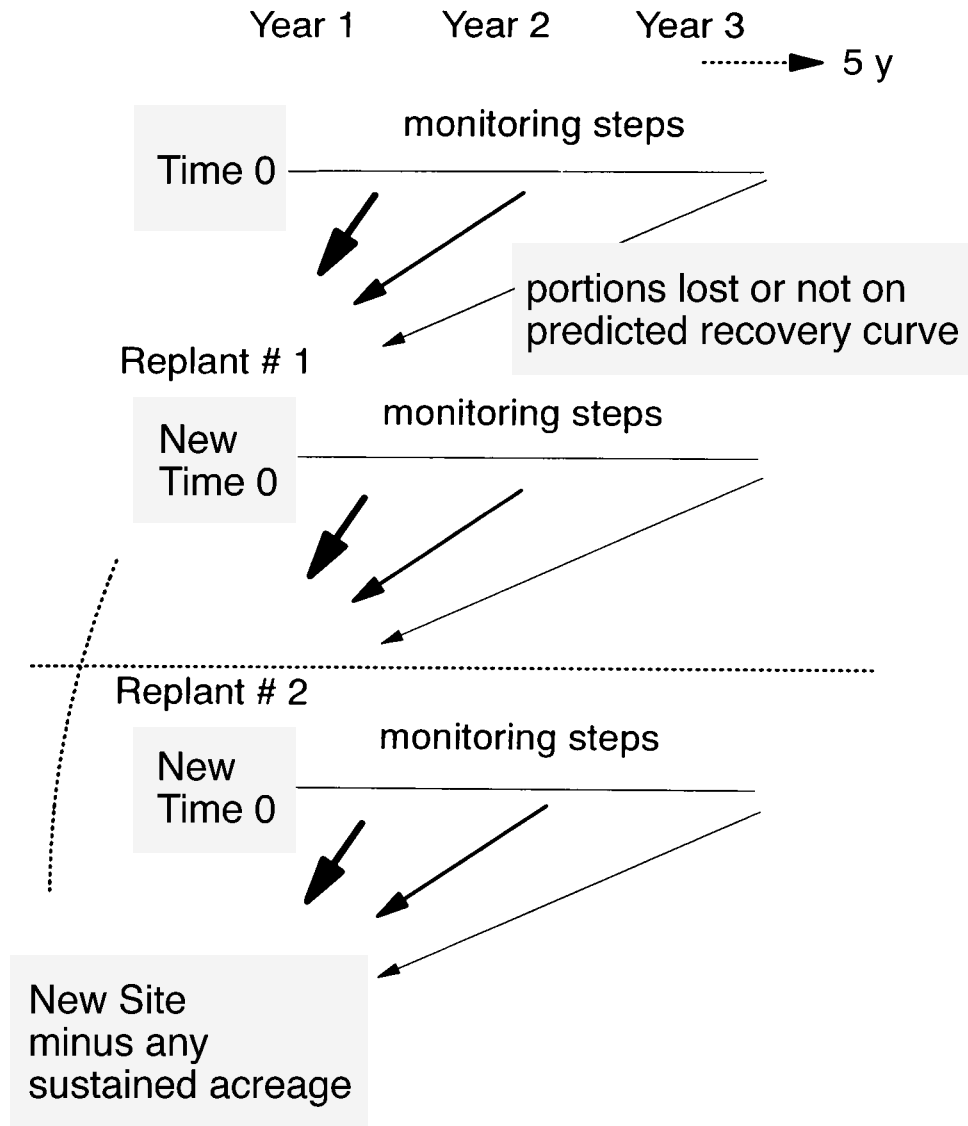
New
Time 0

New Site
minus any
sustained acreage

Figure 4.1. Sequencing of the seagrass planting success criteria. Initial planting is done at Time 0. Monitoring is to continue for a minimum of five years. If at any time a significant loss of planting units (PUs) occurs, then replanting (remedial planting) should be done. Because this tends to happen with greater frequency soon after planting, heavy arrows are used to indicate conveyance to Replanting #1; less heavy arrows are used to indicate the lowered expected frequency of remedial planting as time progresses. Any remedial planting on the original planting site itself means that for those PU, the clock is reset to zero. This prevents chronic replanting right up to the end of the five year monitoring period. If PU losses are again experienced, then a second remedial planting may be called for. At this point the dashed lines indicate that if some clear and overriding problem is evident with the planting site (e.g., repeated large scale losses due to unfavorable environmental conditions), then a decision may be made to select an altogether new site and start over (minus any acreage sustained at the original planting site). However if losses are minimal and actions can be taken to ameloriate the agent of loss (e.g., adding bioturbation exclusion devices), then continued remedial planting would be allowed. Only rarely would any additional replantings be allowed on the original site after two remedial tries. At that point an altogether new site should be considered.

heavy arrows are used to indicate the lowered expected frequency of remedial plant-ing as time progresses.

Any remedial planting on the original planting site means that for those PUs, the clock is reset to zero. This prevents chronic replanting of an unsuitable right up to the end of the three-year monitoring period. If PU losses are again experienced, then a second remedial planting may be called for. At this point the dashed lines (Figure 4.1) indicate that if some clear and overriding problem is evident with the planting site (e.g., repeated large-scale losses due to unfavorable environmental con-ditions), then a decision may be made to select an altogether new site and start over (minus any acreage sustained at the original planting site). However if losses are min-imal and actions can be taken to ameliorate the agent of loss (e.g., adding bioturba-tion exclusion devices), then continued remedial planting would be allowed. Only rarely should any additional replanting be allowed on the original site after two remedial tries. At that point a new site should be considered. Ideally, an alternate site would be selected in the initial site-selection process.

INTERPRETATION OF MONITORING DATA

The computations described above allow a direct comparison on a unit area basis of planted versus lost acreage. Success may then be based on whether the targeted amount of coverage has been generated. This is a quantitative measure which is assumed to be diagnostic of ecological function. If the planting project is for miti-gation, then compliance may thereby be interpreted as both acreage generated and the unassisted persistence of that acreage over time (the three year period). The per-sistence issue is also critical. If the planting does not persist, then the ecosystem has experienced a net loss and the project has not been successful. The population growth and coverage data may be compared periodically with published values (dependent on species and ecoregion) as a relative indicator of performance.

Although these data collections may seem involved, they represent some of the sim-plest and least expensive metrics we found in our survey of planting projects. Moreover, without them cost projections cannot be made and cost overruns can fol-low. In computing costs, it should be recognized that little or no additional care may be required once the plants are established. Natural disturbance (rays, storms) and sea-sonal peaks and troughs in growth are to be expected.

As an example of how these various monitoring conditions we have added an example plan (Appendix E). There, we give specific language for planting site selec-

tion criteria, monitoring, replacement ratio computation surveying with the Braun–Blanquet (1965) method (also see Appendix E, p. 220). The plan was designed with both propeller scars and mooring scars in mind. However, unlike the specialized prop scar portion of the plan, the mooring scar part can be generalized to many plantings that involve broad, open areas that are not in high energy settings. To use the mooring scar part in high water motion areas, apply the decision sequences given in Figures 2.1 and then revise that by applying the decision processes from Figures 2.5, and 3.8.

REAL COSTS OF SEAGRASS TRANSPLANTING

One of the most-asked questions is "how much does seagrass planting cost?" Given the wide variety of seagrass growth strategies and environmental settings under which seagrass beds occur, this is not an easy question to answer. Prices vary widely. Besides the direct influence of project size on cost, the following are some factors that we have seen to generally constitute grounds for increased costs (in an approximate decreasing order of importance):

1. inappropriate site selection,
2. inexperience (inefficiency, poor technique),
3. high disturbance, e.g., bioturbation (actual losses and therefore costs of replanting or exclusion devices which are inherently costly to construct and deploy),
4. water depths that require use of SCUBA divers,
5. low visibility,
6. soft sediments (especially when wading or walking on the site is required),
7. rough seas,
8. cold water planting,
9. capitalization (purchasing equipment: e.g., boats, motors),
10. wide profit margins,
11. amount of site preparation (e.g., creation of subtidal dikes)
12. excessive frequency of monitoring, and
13. overly detailed parameters chosen for monitoring (blade width, length, faunal assessment).

Over the years there is a general trend for seagrass planting costs to be similar to those for salt marsh planting. A recent review by King and Bohlen (1994) found that submerged aquatic plant restoration typically ran between \$19,000 and \$20,000 acre^{-1} (~\$47–49,000 ha^{-1}; albeit based almost exclusively on freshwater work). Thorhaug and

Austin (1976) reported the direct cost of planting seagrass to be ~$25,000 ha^{-1} and Fonseca et al. (1987a) reported collection, fabrication and planting costs to total an estimated $19,000 acre^{-1} (~$46,940 ha^{-1}). The Port of Miami planting project reportedly paid almost $3 million for a +200 acre planting (~$37,000 ha^{-1}; Stein 1984). Plantings in Tampa Bay in the late 1980's were priced at approximately $2.50 PU^{-1} (~$25,000 ha^{-1}) (M.O. Hall, Florida Department of Environmental Protection, St. Petersburg, FL, pers. com.) and more recently we have seen planting projects with monitoring included at ~$49,000 ha^{-1} (K. Fitzpatrick, Sebastian Inlet Tax District Commission, Indiatlantic, FL, pers. com.). Thus, even without corrections for inflation, the price of seagrass planting appeared to have been consistent for nearly the last 20 years, varying with species and the density of plantings, and other extenuating circumstances, but averaging near $37,000 ha^{-1}. There are large cost discrepancies though. For example, if one takes the costs quoted by Zieman (1982) and correct them to 1997 dollars, the cost per acre is in the neighborhood of ~$316,000 ha^{-1}. Therefore, we feel that most of these projects did not accurately compile the real costs associated with launching a restoration or mitigation project. To cost out the project plan described in Appendix E in 1997 US dollars, we used a 12,580 PU, *Halodule wrightii* peat pot planting that requires boat access. The costs included securing aerial photographs (~$5,465), preparing maps and groundtruthing (~$14,314), collecting, preparing and installing (~$64,846), and monitoring with re-fertilization and report writing (~$205,650), and contractor profit of 10% (~$20,028), the total cost was ~$206,000 acre^{-1}, or ~$510,000 per ha^{-1} (a value closer to Zieman's 1982 estimate than more recent estimates from other projects). Our estimate did not include costs incurred by any Government oversight. Although there may be many ways to reduce cost, the discrepancy between ~$37,000 ha^{-1} and over $500,000 ha^{-1} means that large variation in costs can be expected and that it is prudent to conduct a detailed costing before allowing the loss of a seagrass bed.

More recently, some effort has been made to guarantee planting success. However we caution against such guarantees without specific caveats regarding remedial plantings (incidently, terrestrial crops are not guaranteed and there is much more experience in their production). With a planting guarantee, there are three possible outcomes:

1. A very successful planting that requires little or no additional planting is heavily over-compensated, e.g. $100,000 per acre as opposed to the average of ~$15 K acre^{-1} (above: $37 K ha^{-1}).

2. If extensive replanting is repeatedly required up to the end of the guarantee period (if a guarantee limit was set), then no effective mitigation has occurred.

3. If there is no limit and replanting must continue for some indefinite period, then the criteria of success are not met.

Because planting conditions do vary so widely it is sometimes inappropriate to judge each project based on an average cost (see reasons listed above, some of which are difficult to control). Rather, we have historically focused on providing managers with some estimation power by evaluating the costs to harvest plants, fabricate PUs (when a method called for this), and installation of the PUs (Fonseca et al. 1984, 1985, 1987c, 1994). These numbers have been challenged as being too optimistic both by consultants and independent investigators (pers. com.).

The reader must be absolutely clear that the data we have reported should only be used as a guide from which managers may roughly assess costs and from which they can ask questions about what factors are actually contributing to the cost discrepancy they present versus those reported by us in the literature that emphasize only planting costs. These other costs must then be added on, such as break times, travel, training, mobilization and demobilization, materials (usually negligible unless exclusion cages are employed, etc.) and scrutinized for their reasonableness. Because he planting itself cannot be conducted for much less cost than reported for planting alone, any reductions in project cost must be found in other components of the project (i.e., capitalization costs, profit, etc.). We emphasize the heuristic value of these data, recognizing they embody only certain aspects of a larger planting program and can only hope that resource managers utilize these data in that manner.

Our plantings costs in work-minutes for the three categories of effort listed above — collection, fabrication (if appropriate) and deployment of stock — have ranged between ~2 and 3.5 work-minutes PU^{-1} (Fonseca et al. 1994). For a 1-hectare planting on 1-m centers, this means between approximately 340 and 595 work hours of labor. At a given cost (e.g., $10.00 h^{-1}) this gives a fundamental cost of ranging between $3,400 and $5,950 ha^{-1} or an average of ~$1,900 $acre^{-1}$, similar to our previously published data (Fonseca et al. 1984, 1985).